Importance of Lightning NO for Regional Air Quality Modeling

Thomas E. Pierce
Atmospheric Modeling Division
National Exposure Research Laboratory
U.S. Environmental Protection Agency
Research Triangle Park, North Carolina
(pierce.tom@epa.gov)

Presentation at: Global Hydrology and Climate Center
Huntsville, Alabama
October 20, 1999

Sponsor: Dr. Noor Gillani

Introduction

WHAT	**Impact of lightning nitric oxide (NO) emissions on regional photochemistry** Lightning NO emissions are included in the Regional Acid Deposition Model (RADM). The influence of this NO source on regional photochemistry is investigated, and differences in resultant O_3 concentrations are calculated.
WHERE	**Eastern USA** Lightning NO emissions vary temporally & spatially (horizontal & vertical), as well as in source strength (emission intensity). U.S. National Lightning Detection Network (NLDN) data and literature values are used to estimate these emissions for the eastern USA.
WHEN	**July 19 - August 23, 1998** RADM simulations for 25 continuous days have been performed.

Model Formulation

- The Regional Acid Deposition Model (RADM) is a three-dimensional Eulerian grid model developed to simulate the formation and deposition regional photochemical pollutants.

- Model domain consisted of 35 x 38 horizontal grid cells (80 km resolution) and 21 layers.

- Anthropogenic and biogenic VOC and NO_x emissions from 1988 constituted the base case. Lightning NO emission derived from the National Lightning Detection Network (NLDN) were added to the base case for sensitivity testing.

- Meteorological data came from the Mesoscale Meteorological Model Version 5 (MM5).

Lightning NO Emissions

Source: National Lightning Detection Network (NLDN)
July 19-August 13, 1988. Only cloud-to-ground (CG) flashes.
Detection efficiency assumed to be 70%.

<u>GC flashes:</u>

- Flash assigned to corresponding grid cell.
- Each CG flash produces 33 kg NO (Price et al., 1996).
- NO distributed from ~5000 m (layer 17) to the surface.

<u>IC Flashes:</u>

- Assumed 2.7 IC flashes per CG flash (Price and Rind, 1993).
- Each IC flash assumed to produce 1/10 as much NO as a CG flash.
- NO distributed in likely cloud depth (model layers 17-19).

TABLE 1: MODEL LAYERS and STRIKE LOCATIONS

Strike location		layer	sigma	~P(mb)	~H(m)	CG MF	IC MF
	___	top	0.0000	100	16700		
	---	21	0.0500	150	14400	0.0000	0.000
	---	20	0.1500	240	11300	0.0000	0.000
IC	---	19	0.2500	330	9000	0.0000	0.333
IC	---	18	0.3500	420	7200	0.0000	0.333
IC CG	---	17	0.4500	510	5700	0.1667	0.333
CG	---	16	0.5500	600	4400	0.1667	0.000
CG	---	15	0.6500	690	3250	0.1667	0.000
CG	---	14	0.7400	760	2300	0.1333	0.000
CG	---	13	0.8100	840	1650	0.1000	0.000
CG	---	12	0.8525	880	1250	0.0417	0.000
CG	---	11	0.8775	905	1040	0.0417	0.000
CG	---	10	0.9000	925	830	0.0333	0.000
CG	---	9	0.9200	940	660	0.0333	0.000
CG	---	8	0.9375	960	515	0.0250	0.000
CG	---	7	0.9525	975	390	0.0250	0.000
CG	---	6	0.9650	985	285	0.0167	0.000
CG	---	5	0.9750	990	200	0.0167	0.000
CG	---	4	0.9825	1000	140	0.0083	0.000
CG	---	3	0.9875	1005	100	0.0083	0.000
CG	---	2	0.9825	1007	60	0.0083	0.000
CG	---	1	0.9975	1012	20	0.0083	0.000
CG	___	surface	1.0000	1015	0		

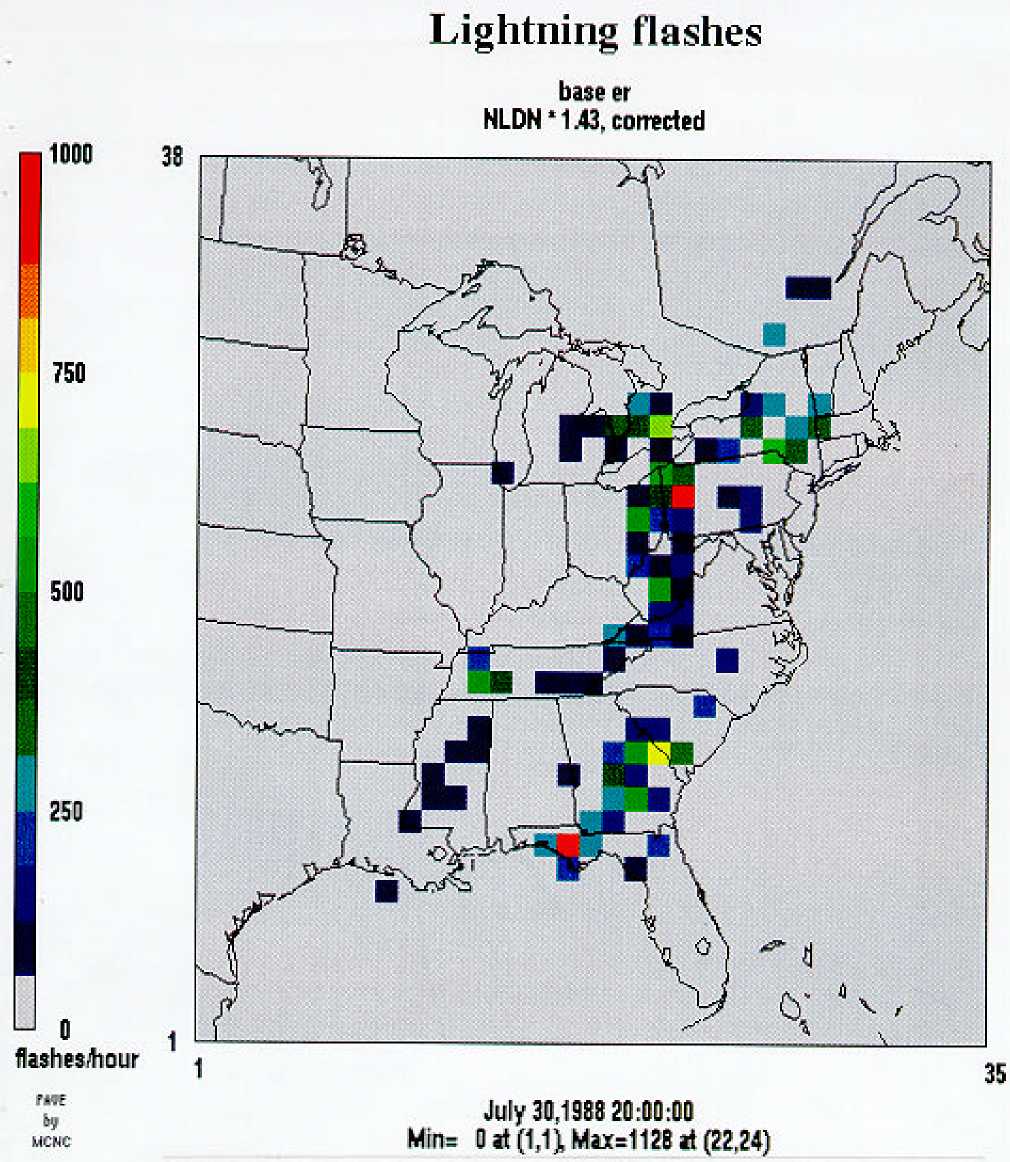


Figure 1: Example of hourly NLDN flash data for hour 20 of July 30, 1988.

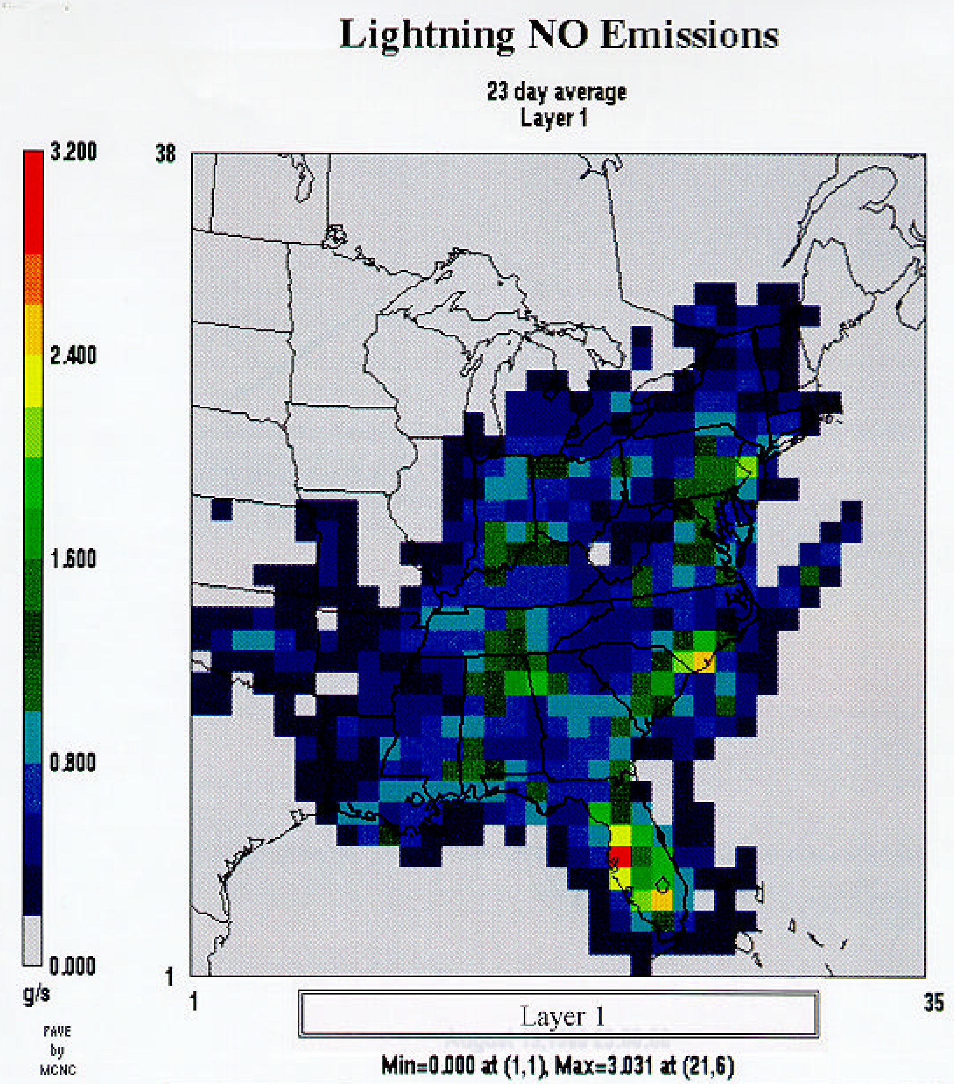
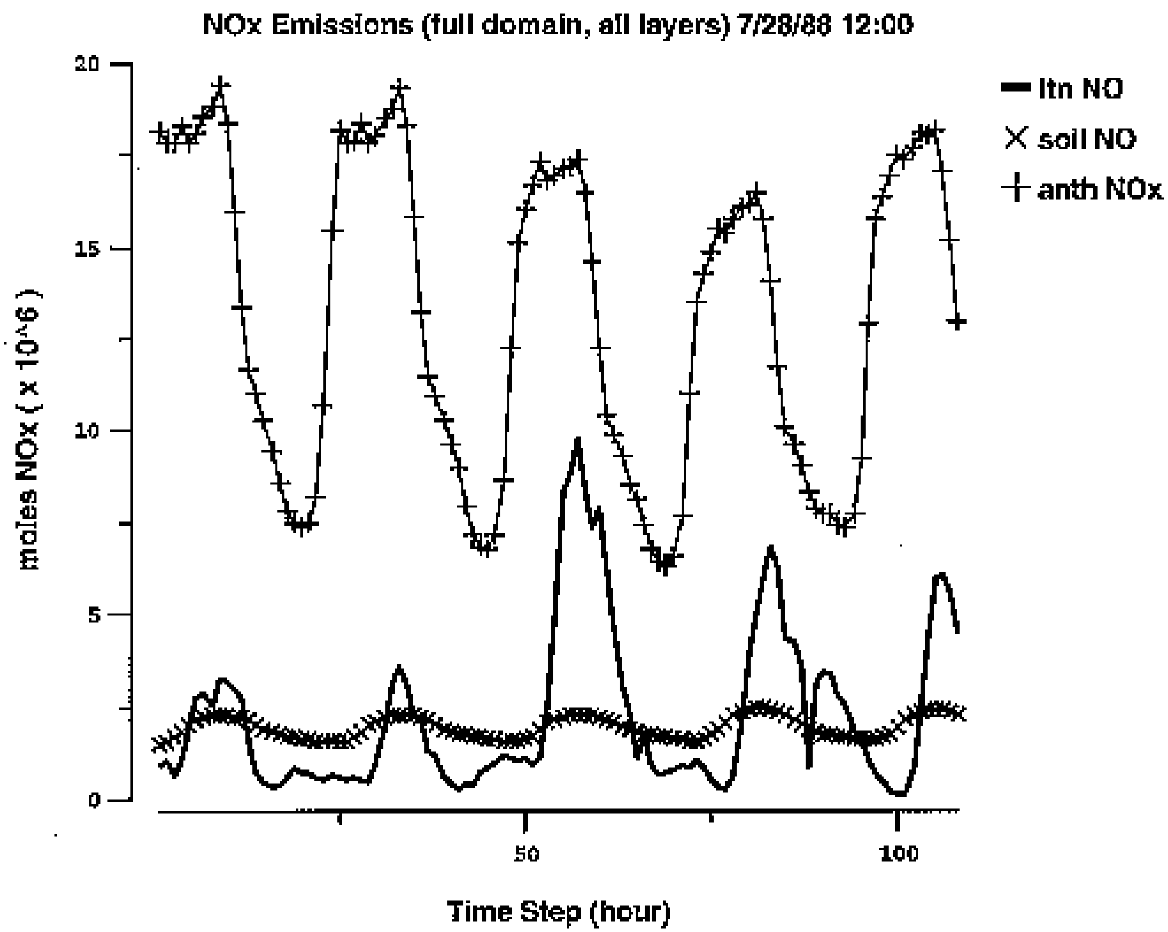


Figure 4: Average NO emissions generated from lightning during July 20 - Aug 6, 1988 period.



NOx Emissions (full domain, all layers) 7/28/88 12:00
ltn NO
soil NO
anth NOx
moles NOx (x 10^6)
20
15
10
5
0
50
100
Time Step (hour)

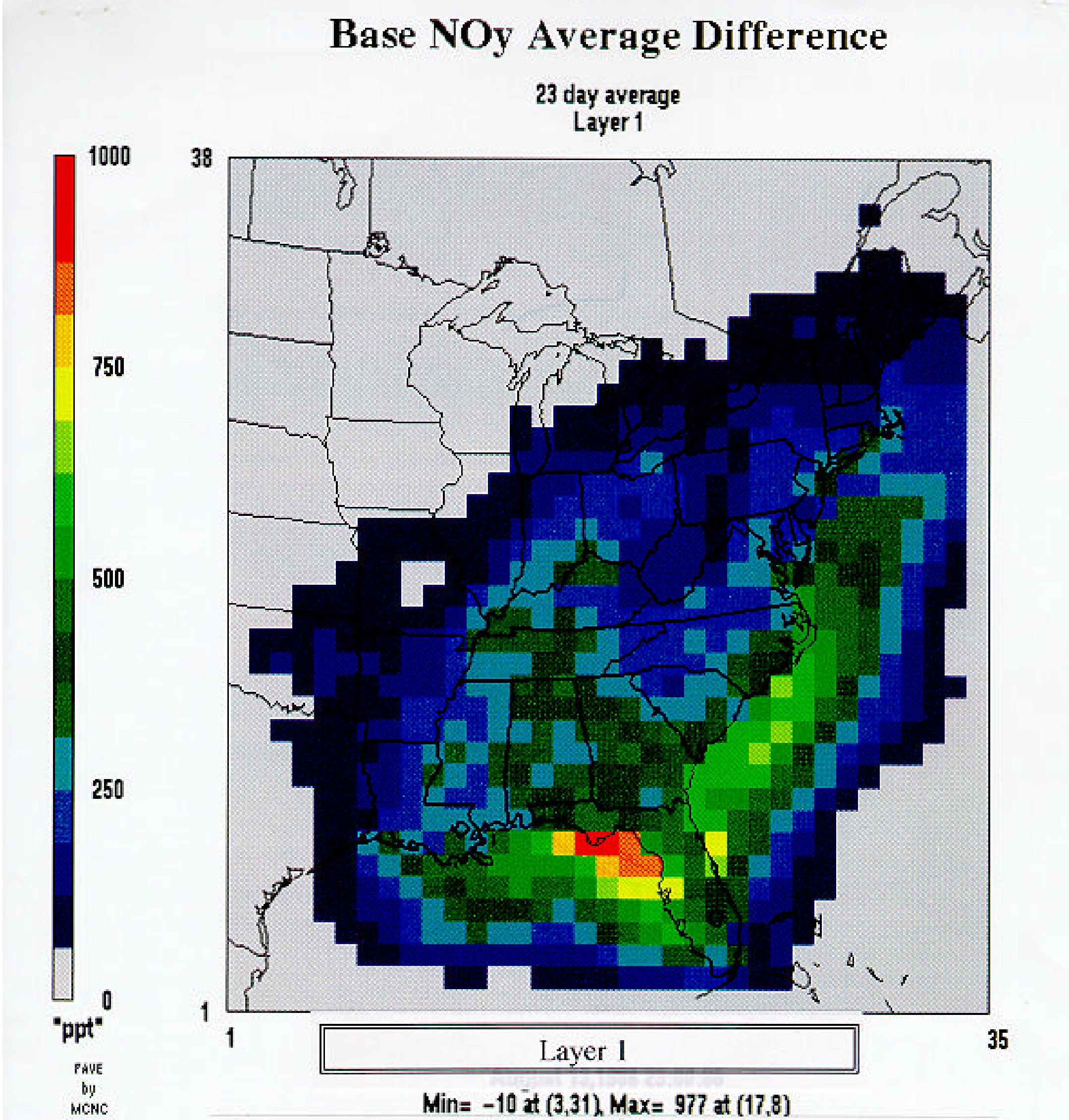


Figure 5: Average difference of resultant NO_y between base case and base case plus lightning NO RADM runs. Note displacement of local maximums from those of the lightning source (Figure 4) due partly to transport.

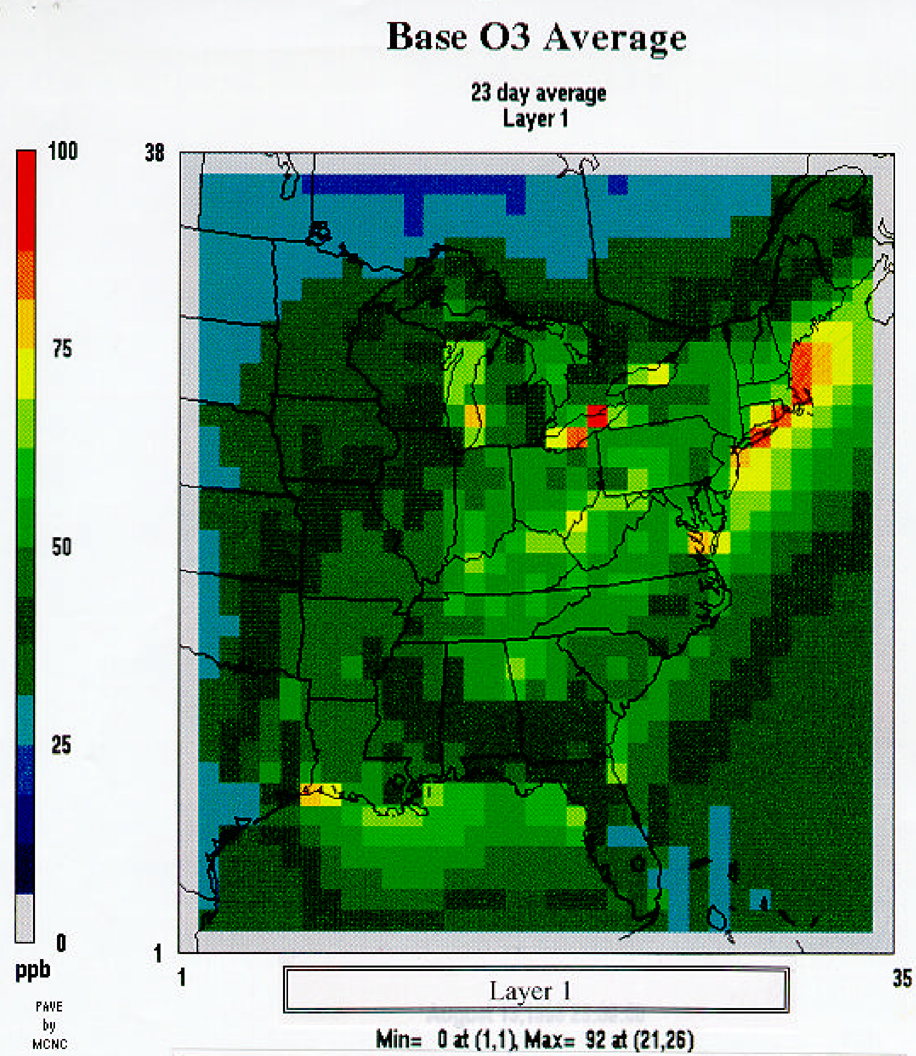


Figure 6: RADM values for 23 day average of O_3 concentration (layer 1) from July 20 to Aug 6, 1988, using base case emissions without lightning NO.

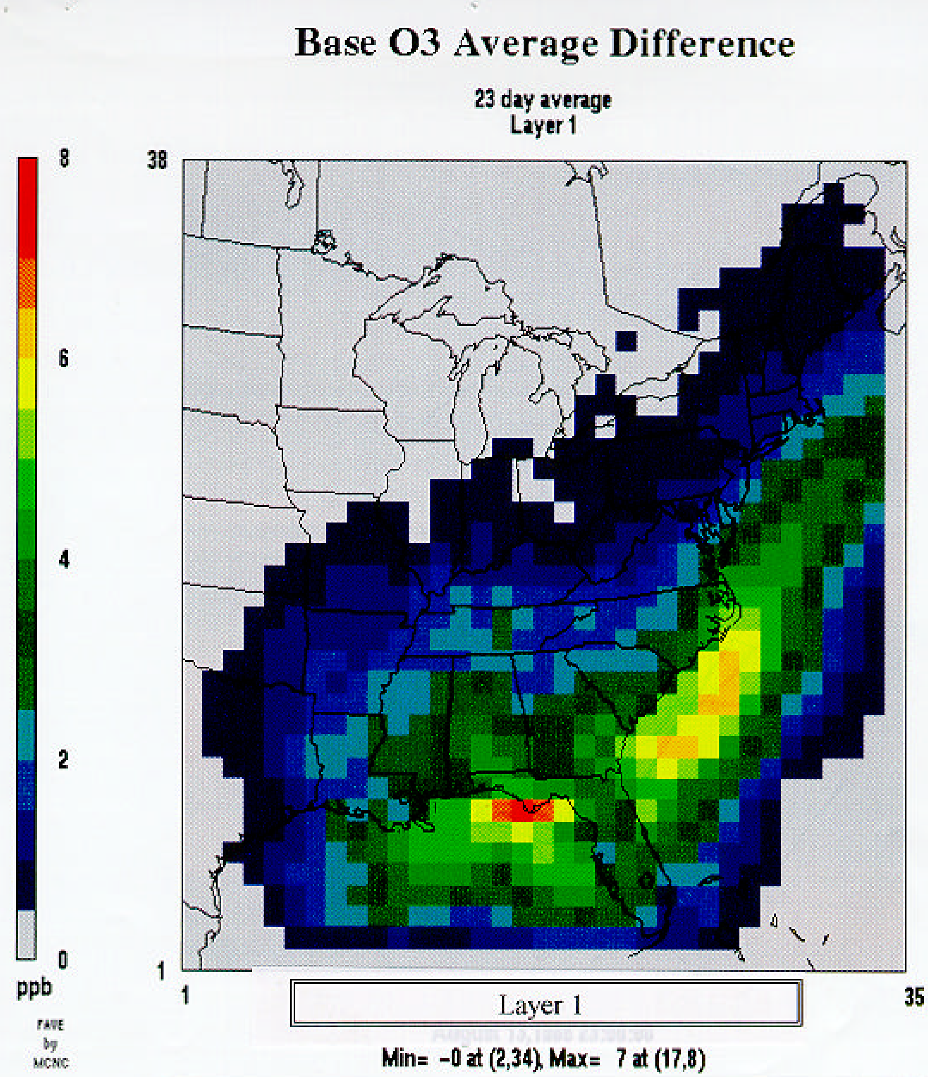


Figure 7: Average difference of O_3 concentration between base case and base case with lightning NO.

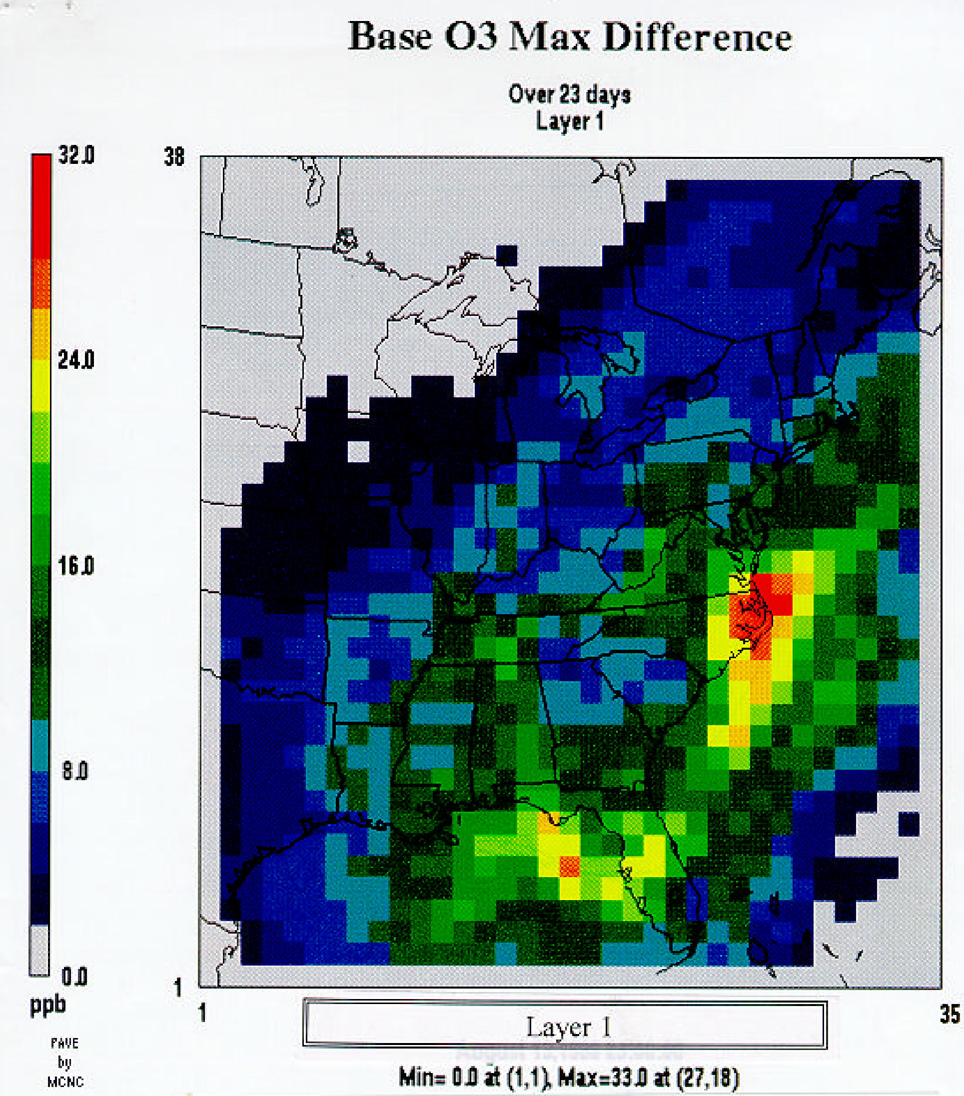
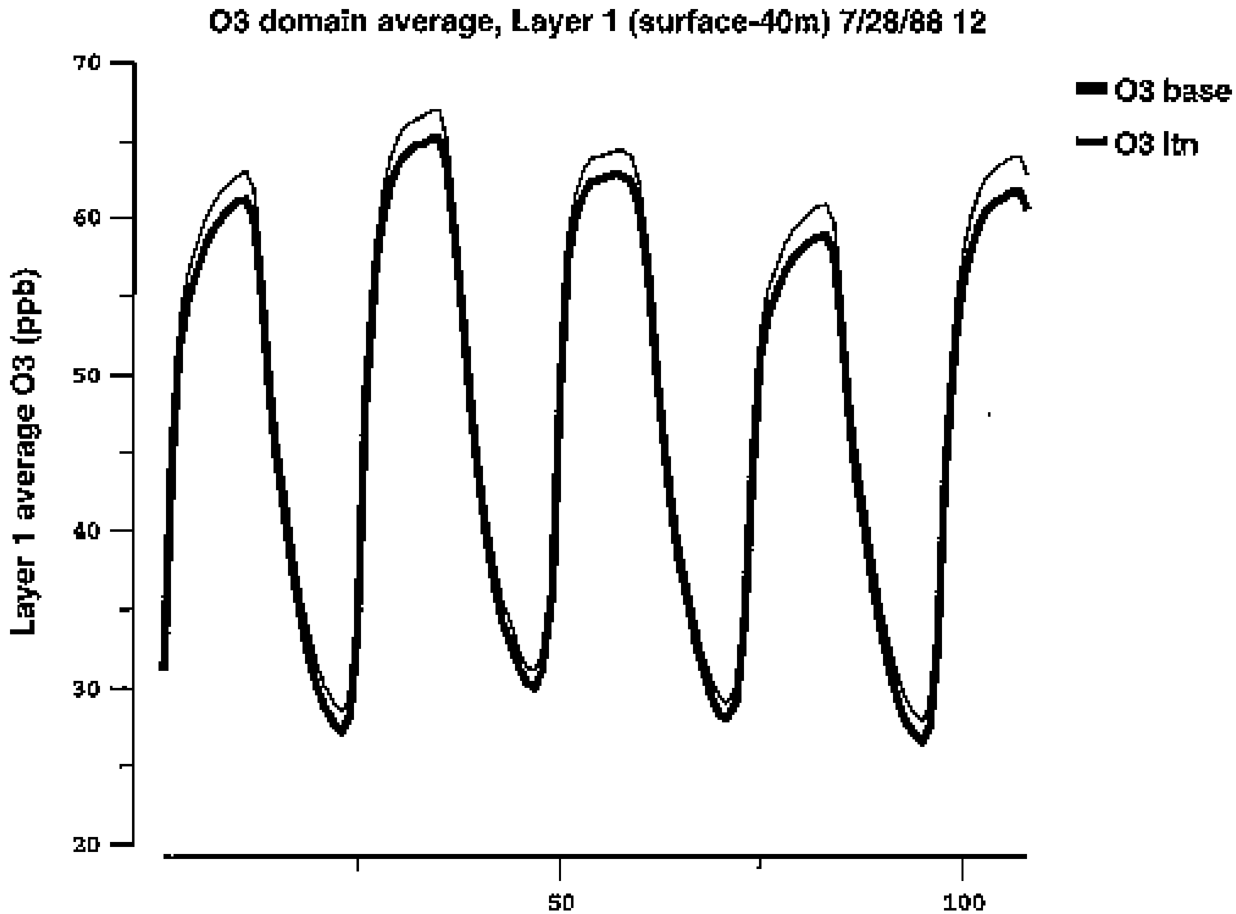
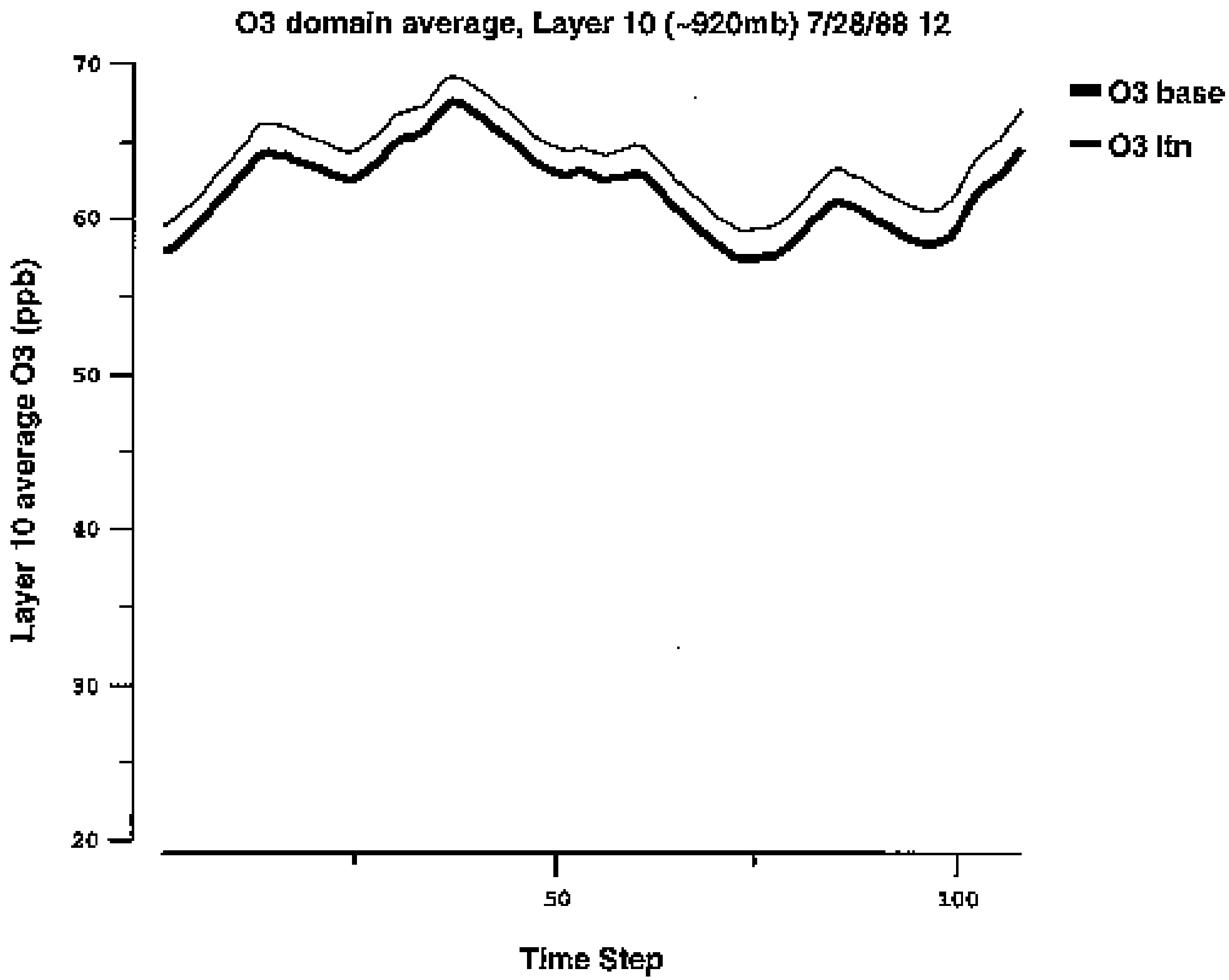


Figure 9: Maximum O_3 concentration for each cell as found over the 23 day period between the base case and base case with lightning NO cases.

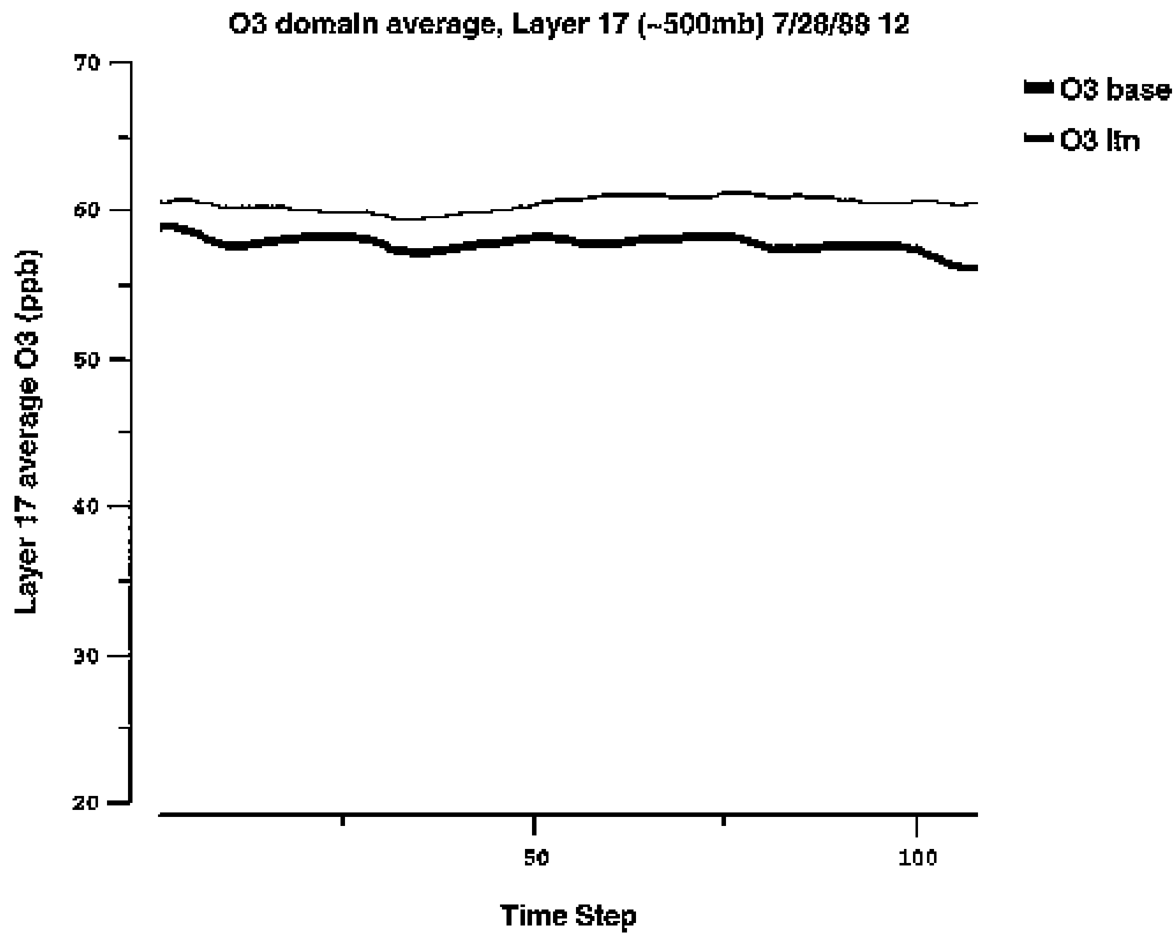


Time Step

Layer 1


O3 domain average, Layer 10 (~920mb) 7/28/88 12
O3 base
O3 ltn
Layer 10 average O3 (ppb)
70
60
50
40
30
20
50
100
Time Step

Layer 10


O3 domain average, Layer 17 (~500mb) 7/28/88 12
70
60
50
40
30
20
Layer 17 average O3 (ppb)
O3 base
O3 lin
50
100
Time Step

Layer 17

Ramifications for Local O_3

- For this RADM simulation*, lightning NO caused average surface O_3 to rise by 2 ppb. Differences were very localized. . .

- On 250 occasions, lightning NO caused O_3 to rise above 120 ppb.

- On 240 occasions, O_3 concentrations >80 ppb increased by >10 ppb.

- On 1550 occasions, O_3 concentrations >60 ppb increased by >10 ppb.

*Simulation is 216h x 33 horz grids x 38 vert grids x layer 1 = 256,608 “occasions.”

Conclusions

- Across the eastern U.S. during the summer, lightning provides a highly variable source of NO, which can be defined in space and time with the National Lightning Detection Network (NLDN).
- In a photochemical model simulation of July 19-August 13, 1988, lightning NO accounted for 11% of total NO_x emissions, raised average surface ozone by 2 ppb, and produced a maximum increase of 33 ppb.
- Recommended model refinements include more accurate NO production rates and improved handling of the vertical distribution and transport of lightning NO.

ACKNOWLEDGEMENTS:

Wendy Richardson, Dyntel

Lucille Bender, Dyntel

Carol Paramore, US EPA/NOAA